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Robert Boyle and his Influence on Thought in the Seventeenth Century

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Robert Boyle and his Influence on Thought in the Seventeenth Century (*)

I

Toward the end of the 19th century Science had begun to exert a profound influence upon the life and thought of all civilized races. DARWIN had shaken the foundations of orthodox religious faith, and the discoveries of GALVANI, VOLTA and FARADAY were presently to transform the conditions of man's existence on the earth. Since then the forces of Nature have been placed under control on a vast scale, the full extent of which was not understood until the advent of the Great War. In addition to material increase in power—be it for good or for evil—there has been a nobler and more far-reaching effect of Science upon the beliefs and actions of mankind; and it is to this phase of the relation between Science and History that I now invite your attention. In recent years scientists have grown self-conscious, perhaps because they have only lately become of age. They realize that they are now a part of the drama of human history, and they look to the professional historian for background and perspective. If in return they can offer anything that will allow him to interpret present-day trends with greater clarity and with more prescience as to the future, they will feel gratified—and happy that a great debt is in part repaid.

To gain an insight into the relation between Science and History we must study our origins and attempt to trace the events which led to Science becoming an integral part of the intellectual equipment of educated men. This is a phase of the development of human culture usually neglected by general historians and

(*) Read December 30, 1931, at a joint meeting of the History of Science Society and the American Historical Association, Minneapolis, Minnesota.

little appreciated by scientific historians because of the great difficulty in obtaining a complete picture of a civilization in any given period. MACAULAY, for example, gives only passing mention to the intellectual revolution that occurred after the Restoration through the activity of men such as BOYLE and HOOKE and NEWTON. (1) Mr. H. G. WELLS (2), more recently, has attempted to portray human history without mention of a physician and with scant reference to the achievements of other scientific men. I am aware that MACAULAY and Mr. WELLS do not, perhaps, fall into the category of professional historians, but I submit that any attempt to depict the march of human events which leaves out scientific and philosophical movements is incomplete and inadequate.

The present paper will recount some of the circumstances which led to the remarkable advancement of Science in the 17th century and to its influence upon the thought of that period, and I propose to weave the story about the name of ROBERT BOYLE, for I believe that BOYLE did as much, and perhaps more, to establish Science as an integral part of the intellectual life of ordinary men as any of his predecessors or contemporaries. He was, moreover, a pioneer and his life and his work therefore merit our closest attention and study.

BOYLE was a child of his time, favored by Fortune and blessed with an industrious nature. In the course of his life he published forty-two books and as many scientific papers, but the weaknesses of his age were as much a part of his character as its virtues. He combined Theology and Science; he recommended impossible nostrums and quack remedies for the ailments to which the flesh is heir; and he believed in the transmutation of gold into the baser metals. And yet it was perhaps these very foibles of his scientific career that made him intelligible and appealing to men in the ranks. NEWTON, his contemporary, lived in an airy sphere which few could penetrate—he wrote in Latin and was indifferent to praise. BOYLE, to be sure, walked humbly, but he spoke and wrote a language that uneducated men could

(1) MACAULAY, T. B. *History of England from the Accession of James II*, London, LONGMANS, 1848-55. MACAULAY mentions NEWTON several times but the names of BOYLE and HOOKE do not occur.

(2) WELLS, H. G. *The Outline of History*, London, 1923.

read and understand, and this accounts in large measure for the influence he exerted.

Before describing BOYLE's career we may allude briefly to the events which led to the scientific renaissance of the 17th century.

II

In ancient times study of the secrets of Nature had little influence upon philosophy, or upon affairs of state. PLATO and SOCRATES were content to contemplate the universe subjectively, and it is difficult to persuade oneself that ARISTOTLE's ethics or his other philosophical conceptions were greatly influenced by his intimate knowledge of natural phenomena. This of course is a debatable point, and it should be regarded as an expression of a tendency rather than as a final judgment concerning ARISTOTLE's contribution. The change in outlook might have come in the 2nd century of the Christian era when GALEN, the private physician of MARCUS AURELIUS, began to investigate the functions of living organisms. He was the first to pursue the experimental method in Science on an extensive scale but he did not transform Man's attitude toward the universe because of his 'time'—which he failed to ripen—and because as a philosopher he was at best mediocre.

The real change in point of view came at a much later period in history. The intellectual ferment of the early Renaissance culminated in the year 1543, when VESALIUS and COPERNICUS brought forth their epoch-making books. After November 1543 the earth was no longer a flat center of the universe, but a sphere as COLUMBUS had thought—one of many revolving about the sun. Mankind was slow to accept the new truths for COPERNICUS's book was written in Latin and few were equipped to comprehend its tables and mathematical symbols. It bore the title, *De Revolutionibus Orbium Coelestium* and it caused the greatest revolution that has ever occurred in Man's attitude toward the universe. The Roman Church, however, was so completely committed to the Ptolemaic system that the book was placed immediately on the *Index* (3) (by the Pope to whom it was dedicated), and it

(3) The first *Index Librorum Prohibitorum* of the Roman Church was drawn up between 1543 and 1546 by Pope PAUL III, to whom COPERNICUS had dedicated

was not removed until the year 1822! A copy of the book recently acquired by the Yale University Library (4) has many of the heretical passages crossed out in contemporary ink, evidently by the hand of some 16th-century ecclesiastic.

VESALIUS's book, which also appeared in 1543, exerted a wide influence but it was less far-reaching in respect of philosophical conceptions. As a monument of human industry there are few parallels to the *De Humani Corporis Fabrica*, a glorious folio published when its author was 28 years of age. It contains a faithful record of the structure of the human body but, as Professor SIGERIST has pointed out, its point of view was essentially 'static' and the real change in biological philosophy came, not with VESALIUS but at a later date, with the discoveries of WILLIAM HARVEY. The new idea of movement and action for which HARVEY stood has lately been symbolized by Professor SIGERIST (5) in his use, somewhat alarming at first thought, of the word "baroque". The point of view of VESALIUS and of HARVEY's master, FABRICIUS, was static and could be symbolized by straight lines. The philosophy of HARVEY was one of movement and curves—" baroque "—and out of it came the great discovery of the motion of blood in a circle. Men then began to consider other problems of functional activity : respiration, muscular contraction, the reflex movements of decapitated insects, and a hundred other problems that would not have suggested themselves had not a new outlook been forced on the human mind.

HARVEY was born in 1578; his announcement of the discovery of the circulation was made orally in 1615 but his book was not published until 1628; he died in 1657. FRANCIS BACON had meanwhile become an ardent exponent of the experimental

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his book. Before that time local indexes had been published in various countries but they did not have the official sanction of the Papacy. The first index published by the Papacy was issued by PAUL IV in 1559 and bears the title *Index auctorum et librorum, qui ab Officio Sanctae Rom. et Universalis Inquisitionis caveri ab omnibus.* (Reusch, Fr. Heinrich. *Die Indices Librorum Prohibitorum des sechzehnten Jahrhunderts*, Tübingen, Litterarischer Verein in Stuttgart, 1886, 598 pp. *Index der verbotenen Bücher*, 2 vols., Bonn, MAX COHEN & Sohn, 1883-85, 624 + 1266 pp.)

(4) Obtained from Professor J. S. TURNER of Iowa State College, Ames, Iowa. It had appeared in *Sotheran's Price Current of Literature*, No. 828, 1931.

(5) Lectures at the Institute of the History of Medicine, Johns Hopkins University, November 5, 1931. To be published by The Johns Hopkins Press.

method (6) and had foreseen the need of a scientific academy. As an appendix to the second edition of *Sylva Sylvarum* which appeared in 1628, two years after BACON's death, RAWLEY, his editor, issued his *New Atlantis*. The need for an organized scientific institution is here for the first time set forth, and the further point is emphasized that scientists require, above all things, collaboration and protection. The universities are not referred to in the *New Atlantis* and the idea that Science might develop within their walls had apparently not passed through VERULAM's mind. From these beginnings modern scientific institutions arose, for the Royal Society, which was incorporated in 1662, was admittedly founded on BACON's great conception. Unwittingly the Lord Chancellor of England had begotten a new and protesting offspring whose lusty voice was ultimately to be heard to the ends of the earth.

One may smile at the conservatism of the Church of Rome in refusing to accept the Copernican system until 1822 when it was forced upon it by the subsequent discoveries of TYCHO BRAHE, KEPLER, NEWTON, LAPLACE, and the HERSCHELS; but this conservatism is not to be compared with the arrogance of the chief centers of learning with regard to Science as a whole. With a few brilliant exceptions, chiefly among the Dutch universities, the heavy hand of classical tradition persisted without essential modification until the late 18th cenrury. Most administrative offices were held by theologians and all instruction was in Latin. The Bachelor's degree was granted on completion of a four years' course, involving study of grammar, logic, rhetoric, arithmetic, geometry, and astronomy. The astronomy was Ptolemaic, the mathematics Euclidian, and the logic entirely Aristotelian. If one proceeded to a higher degree, *e.g.* in medicine, before the end of the 17th century, knowledge of GALEN and HIPPOCRATES was all that was required, and four to seven years were spent in obtaining the degree. Outside the medical faculty the textbooks were mainly Aristotelian. Didactic lectures were given, and in addition to attending these students defended their theses at public disputation. " These disputations were never supposed to bring in new subject matter; they were only to give the student

(6) BACON, F. *Two Books of the Advancement of Learning*, London, 1605.

a chance of combining and recombining, of practising and exercising, what he had acquired from Aristotle or other authorities. This feeling of the finality and sufficiency of what had been discovered by the standard Greek writers was at once the most characteristic and most pernicious feature of the system. At these disputations the professor presided, and saw that the arguments proceeded along the strict lines laid down by Aristotle's logic." (7)

In tracing the history of the experimental method I pointed out a year ago (8) that the great scientific societies such as the Accademia del Cimento, the Leopold Academy, and the Royal Society came into being largely because the universities refused to admit Science within their walls. This spirit of intolerance has in fact died almost as hard as the Papal *Index*, for we must remember that the acceptance of Science by the universities has occurred largely within the last 50 years. The Renaissance in university life which followed the appearance of strong scientific faculties is scarcely to be regarded as a coincidence.

It is a fact of peculiar significance, therefore, that the centers of learning of the 17th century had little to do with the fostering of Science, and this is particularly well exemplified by the career of ROBERT BOYLE.

III

A few weeks before his death BOYLE published one of his less important scientific treatises, in the preface of which he

(7) ORNSTEIN, M. *The Rôle of Scientific Societies in the Seventeenth Century*, Columbia Ph. D. thesis, published privately, New York, 1913 (Reprinted, University of Chicago Press, 1928), 248-49. After this passage Miss ORNSTEIN cites the following passage from ACQUAVIVA, the Jesuits' *Ratio Studiorum*, as illustrating the spirit of the universities in the 17th Century : " The teacher is not to permit any novel opinions or discussions to be mooted; nor to cite or allow others to cite the opinions of an author not of known repute; nor to teach or suffer to be taught anything contrary to prevalent opinions of acknowledged doctors current in the schools. Obsolete and false opinions are not to be mentioned at all even for refutation nor are objections to received teaching to be dwelt on at any length... In philosophy Aristotle is always to be followed and St. Thomas Aquinas generally..."

(8) FULTON, J. F. " The Rise of the Experimental Method," *Yale Journal of Biology and Medicine*, 1932, *iii*, 299-320.

expresses the hope that his observations, " may be taken in good part from a Person... that was never a Professor of Philosophy, nor so much as a Gown-man." (9) This, I believe, gives the keynote of BOYLE's career. He never assumed the responsibilities of a university position, probably because the atmosphere was not congenial and he preferred his independence. Furthermore, though he was created " Doctor of Physick " at Oxford in 1665, he was never a student at any university and obtained his education entirely from tutors and travels.

The seventh son and fourteenth child of RICHARD BOYLE, first Earl of Cork, ROBERT BOYLE was born at Lismore, County Cork in Ireland, on January 25th, 1627. His father had gone to Ireland in 1588 as a clerk in the service of Queen ELIZABETH, and within ten years he had become the most wealthy and powerful landholder in Ireland. His mother was a kindly but not brilliant woman who died shortly after ROBERT's birth through complications incident to bringing her fifteenth child into the world. BOYLE's brothers and sisters inherited his father's shrewdness and some of his brothers had also that strain of unscrupulousness which must have played some part in the rapid growth of his father's fortunes. (10) ROBERT himself seems to have inherited his industry and his alertness of mind. His other traits of character began to appear during his years at Eton and it would be unwise to attribute them either to nature or nurture. Sir HENRY WOTTON, the provost of Eton, was quick to recognize that ROBERT was an unusual student and he soon placed him in the hands of a judicious and far-seeing tutor named MARCOMBES. With him ROBERT travelled on the Continent and added to his careful grounding in classical tongues a thorough familiarity with French, German, and Italian.

On returning from the Continent BOYLE stayed with his sister, Lady RANELAGH, in London, retiring from time to time to his

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(9) BOYLE, R. *Experimenta et Observationes Physicae*, London, 1691, f. A7*b*. In *The Excellency of Theology*, published in 1674, he remarked similarly, " I am no lecturer or professor of physics." (f. A5*a*.)

(10) The publication of the *Lismore Papers* in 1911 (edited by Rev. ALEX GROSART, 10 vols.), in which the EARL OF CORK's remarkable diary was for the first time made available, has done much to dispel the incredulity and suspicions of doubtful integrity which had long existed concerning him.

country estate at Stalbridge in Dorset, and he soon found himself the center of an active group who, after 1645, began to meet together from time to time with a view to discussing scientific problems and to " increasing natural knowledge by means of experiment ". They referred to themselves as the " Invisible College." The story of how this group later moved to Oxford and later still returned to London, to become incorporated in 1662 as the Royal Society of London, has been frequently told and need not be repeated here. That BOYLE, even before the age of twenty, was a moving spirit in the group is clear from an abundance of contemporary evidence. (11) His name is invariably mentioned in the early descriptions of the " Invisible

(11) The first direct reference to the " Invisible College " that has come down to us occurs in a letter of BOYLE to MARCOMBES written from London, October 22, 1646. The letter is long and gives a most interesting account of the political troubles of the day. At the end is the following remarkable paragraph : " The other humane studies I apply myself to, are natural philosophy, the mechanics, and husbandry, according to the principles of our new philosophical college, that values no knowledge, but as it hath a tendency to use. And therefore I shall make it one of my suits to you, that you would take the pains to enquire a little more thoroughly into the ways of husbandry, &c. practised in your parts; and when you intend for *England*, to bring along with you what good receipts or choice books of any of these subjects you can procure; which will make you extremely welcome to our *invisible college*, which I had now designed to give you a description of."

Several months later in a letter also from London, dated February 1646-7, to Mr. FRANCIS TALLENTS, a fellow of Magdalene College, he says : " The best on't is, that the corner-stones of the *invisible*, or (as they term themselves) the *philosophical college*, do now and then honour me with their company, which makes me as sorry for those pressing occasions, that urge my departure, as I am at other times angry with that solicitous idleness, that I am necessitated to during my stay."

There is a third reference to the " Invisible College " at this time in a letter of May 7th, 1647 addressed to SAMUEL HARTLIB, MILTON's close friend : " Besides this, I say, you interest yourself so much in the *Invisible College*, and that whole society is so highly concerned in all the accidents of your life, that you can send me no intelligence of your own affairs, that does not (at least relationally) assume the nature of *Utopian*." (BIRCH, THOMAS. *The Works of the Honourable Robert Boyle in Five Volumes. To which is prefixed The Life of the Author*, 1st ed., London, A. MILLAR, 1744, *i*, 20, 24.

The paragraph from the letter to MARCOMBES indicates that the " Invisible College " had been in existence for some time and that apparently BOYLE had been regularly attending their meetings. His statement of its aim (*i.e.*, that it values no knowledge, but as it hath a tendency to use) is an inadequate statement of their ultimate objectives as set forth later in *The Usefulness of Experimental Philosophy*.

College." In 1651, when BOYLE was only twenty-three, we find NATHANIEL HIGHMORE seeking his patronage by dedicating his book *The History of Generation*, " to the Honourable, Mr. ROBERT BOYLE, son to the Right Honourable the late Earl of CORK... Being ravisht, Sir," HIGHMORE says, " with these considerations of your worth and candor, I shall not fear to throw these Papers into the bosom of your protection; from whom as I cannot misse a judicious censure, so I shall hope for a candid reception."

By 1651 BOYLE had already begun to try his hand at writing but he had published nothing. *Seraphick Love* and *A Discourse against Swearing* were already in manuscript and *The Usefulness of Experimental Philosophy*, which was published in 1663, in which he sets himself down as an ardent protagonist of the experimental method, was written about 1650, for he says in the ' Author's Advertisement ' that the first part of the book was written " 10 or 12 years ago (when I was scarce above 21 or 22 years old). " This is important since it means that BOYLE had been preaching the gospel of experiment long before the Royal Society was founded.

After a trip to Ireland in 1653 BOYLE returned to England and in June 1654 he went to reside in Oxford. There he could live relatively undisturbed by the political distractions of the time and he was able to enjoy the society of a few friends who were particularly congenial, several of whom had been among the " Invisibles " in London. Among them were CHRISTOPHER WREN, who at that time was interested in mathematics and astronomy; JOHN WALLIS, the geometer, SETH WARD, the Savilian professor of astronomy, and THOMAS WILLIS, the physician. In this friendly atmosphere BOYLE was able to indulge his taste for reading and to continue his chemical experiments. He did not join a college and it does not appear that he frequented the colleges apart from occasional meetings at Wadham.

In 1658 BOYLE secured the services of an impecunious student chorister of Christ Church bearing the name of ROBERT HOOKE, who materially assisted him in constructing an air pump. With this instrument BOYLE began the memorable series of investigations which, in 1660, led to the publication of his first scientific book, *The Spring and Weight of the Air*, and in 1662 to the formulation of the celebrated gas law that still bears his name.

Before describing BOYLE's contributions to Science, it will be illuminating to dwell for a moment upon his habits of writing and publishing.

IV

BOYLE's career as a writer began in 1659 with the publication of a devotional tract, a *pièce de jeunesse*, written many years before and entitled *Some Motives and Incentives to the Love of God*, better known as *Seraphick Love*, and it ended in 1695 with a posthumous publication, *A Free Discourse Against Swearing*, also one of BOYLE's juvenilia, making a total of forty-two books which had come from his prolific pen. Many of them had passed into successive editions, continuations, and even added volumes. Of the forty-two titles thirty are scientific treatises and, with the exception of the tract advertising the loss of his writings, the remainder are either theological tracts or philosophical dialogues. His theological writings do not concern us. The scientific works are difficult to classify since in nearly every one he included important observations on physics, chemistry, physiology, and medicine. In addition to his separately published treatises there were thirty-five papers contributed to the *Philosophical Transactions* of the Royal Society. In preparing a bibliography of the works of BOYLE (12) I have recently had occasion to peruse carefully and to compare all of the original editions of BOYLE's various books. They form a particularly interesting chapter in the history of 17th-century book-making and have thrown significant light upon the practices of 17th-century printers and authors. BOYLE himself was a very untidy writer. His ' copy ' was often illegible and he was given to after-thoughts which were pitch-forked into the body of a book after it had been set up in page form. This meant insertions, displacement of signatures, mispagination, and the bewilderment of binders. Many of BOYLE's works are in consequence gathered erratically and are often incomplete.

In the broad field of Science there was little that he did not touch, " and almost every branch of modern Science can trace

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(12) FULTON, J. F. " A Bibliography of the Honourable Robert Boyle," *Proc. Oxf. Bibliog. Soc.*, 1932, *iii*, pp. 1-160.

phases of its origin in his writings... weighing the air, the thermometer, the barometer, freezing mixtures, the gas laws, the definition of chemical elements, phosphorus, phosphorescence, electricity, all these things are intimately associated with his name." (13) Since it will be impossible to deal with all phases of BOYLE's scientific career I propose to restrict my remarks to two themes which he studied throughout his active life : the nature of combustion and respiration, and his beliefs concerning the atomic structure of matter, particularly the gases.

V

RESPIRATION AND COMBUSTION

Many hold that the history of a science should consist in the record of the development of ideas without reference to the lives of the men who created them. This, the dispassionate approach of many modern scholars, has been applied to Philosophy and to certain branches of Science, but I cannot believe that it represents history in the fullest sense of the term. Once an idea is separated from its creator it becomes impossible to see either one clearly; moreover, many believe that the way a man lived and worked is more revealing and stimulating to those of a later age than what he did. This is particularly true of the development of ideas concerning respiration and combustion, for here our final judgment is to a large extent colored by knowledge of the personalities involved : *e.g.*, the iconoclastic PARACELSUS, the irascible HOOKE, MAYOW the dreamer, the fastidious LOWER, and BOYLE.

Professor T. S. PATTERSON of Glasgow has recently published a paper (14) bearing on the subject, that has made all historians

(13) *Ibid.*, p. 5.

(14) PATTERSON, T. S. " John Mayow in Contemporary Setting : A Contribution to the History of Respiration and Combustion," *Isis*, 1931, *xv*, 47-96; 504-546. His conclusion may be quoted here : " MAYOW was not the *first* to show that a candle enclosed in a flask goes out while there is still, apparently, abundance of air; he was not the *first* to infer that air is heretogeneous; he was not the *first* to suggest the existence in air of a vital substance also to be found in nitre and nitric acid; he was not the *first* to call this substance nitro-aerial spirit; he was

of Science catch their breath. JOHN MAYOW, an obscure physiologist of Oxford, probably born in 1643, has been proclaimed in all histories of chemistry and physiology as the one who had first enunciated the modern theory of respiration and combustion, namely that the air contributes a substance essential to both processes. Professor PATTERSON has marshalled a devastating number of passages from distinguished historians of Science indicating clearly that no one of them had examined their sources critically and that, in point of fact, MAYOW's ideas were not original but had been borrowed largely from the observations and conclusions of ROBERT BOYLE, published eight and fourteen years previously.

Professor PATTERSON has in my opinion proved his point beyond any shadow of doubt. It is not commonly known that BOYLE dealt with respiration and combustion as early as 1660 in his first scientific work, *The Spring and Weight of the Air*, historians having generally associated this work solely with his discovery of the gas law. In addition to weighing the air BOYLE here dscribed the generation of " air " from the action of aqua fortis on iron filings. Then, in a remarkable chapter entitled " A digression containing some doubts touching respiration " (which deserves some time to be reprinted in full) he showed that birds and mice die within 30 seconds to a minute of the time that air is removed from a receiver by means of an air pump. When

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by no means the *first* to show that gun-powder can burn without the assistance of air; he was not the *first* to prove—if he made the experiment at all—that the calx of a metal was heavier than the metal; he was not the *first* to show that an animal placed in a closed vessel died more quickly if a lighted candle was also placed in the vessel. It was not MAYOW who *first* suggested that animals exhaust the air of some constituent necessary to life which enters the blood in breathing; and he was not the *first* to infer that this part of the air was the nitro-aerial spirit, and if he was not the first to show or suggest these things, why should he be credited with them? Moreover, he said nothing about combustion in 1669. The only statement which is *partially* correct is that MAYOW attributed the increase of weight on calcination of antimony—he did not extend the suggestion to other metals—to combination with igneo-aerial particles, but, as has been shown above, §§ 78, 127, this was merely the adoption of a notion already published by BOYLE, and, in addition, since MAYOW's idea of nitro-aerial spirit was very different indeed from our notion of oxygen, it could lead neither MAYOW nor his contemporaries any way towards a comprehension of combustion and respiration. Therefore it was ignored, and quite rightly so. MAYOW's so-called ' discovery of oxygen ' (see §§ 10, 16, 18, 19) was not forgotten; it was never made." (p. 538).

allowed to remain in the same receiver sealed tight but not exhausted of its air, the animals may live on for 30 to 40 minutes. To cite his own picturesque description : " Another Bird being within about half a minute, cast into violent Convulsions, and reduc'd into a sprawling condition, upon the Exsuction of the Air, by the pitty of some Fair Lady's (related to Your Lordship) who made me hastily let in some Air at the Stop-cock, the gasping Animal was presently recover'd, and in a condition to enjoy the benefit of the Lady's Compassion. And another time also, being resolv'd not to be interrupted in our Experiment, we did, at night, shut up a Bird in one of our small Receivers, and observ'd, that for a good while he so little felt the alteration of the Air, that he fell asleep with his head under his wing; and though he afterwards awak'd sick, yet he continu'd upon his legs between forty minutes and three quarters of an hour; after which, seeming ready to expire, we took him out, and soon found him able to make use of the liberty we gave him for a compensation of his sufferings." (15)

Then BOYLE pertinently remarks : " Perhaps... there is some use of the Air which we do not yet so well understand, that makes it so continually needful to the Life of Animals. *Paracelsus* indeed tells us, *That as the Stomack concocts Meat, and makes part of it useful to the Body, rejecting the other part, so the Lungs consume part of the Air, and proscribes the rest.* So that according to our Hermetick Philosopher ... we may suppose, that there is in the Air a little vital Quintessence... which serves to the refreshment and restauration of our vital Spirits, for which use the grosser and incomparably greater part of the Air being unserviceable, it need not seem strange that an Animal stands in need of almost incessantly drawing in fresh Air. But though this opinion is not... absur'd,... it should not be barely asserted but explicated and prov'd." (16)

(15) BOYLE, R. *Spring and Weight of the Air*, London, 1660, p. 361.

(16) *Ibid.*, p. 362. I cannot refrain from citing here one further passage which contains a remarkable forecast concerning the nature of mountain sickness : " That (on the other side) an Air too much dilated is not serviceable for the ends of Respiration, the hasty death of the Animal we kill'd in our exhausted Receiver, seems sufficiently to manifest. And it may not irrationally be doubted, whether or no, if a Man were rais'd to the very top of the Atmosphere, he would be able to live many minutes, and would not quickly dye for want of such Air as we are

In the second edition of *The Spring and Weight of the Air* BOYLE again discusses respiration and combustion but remarks that he could not reach more definite conclusions until he had examined the matter more deliberately. This he did not do until 1674, the year in which MAYOW published his *Tractatus Quinque*. MAYOW had meanwhile published his tract on respiration in 1668 (17) in which a careful summary is given of BOYLE's work and the work of LOWER, HOOKE and others who had written between 1660 and 1668. I entirely concur in Professor PATTERSON's statement that there was nothing original in MAYOW's treatise and that the new ideas it expresses were wrong.

BOYLE's *Suspicions about some Hidden Qualities in the Air*, which appeared in 1674, gives his considered opinion concerning the nature of combustion. Professor PATTERSON does not quote from this remarkable tract, and had he been familiar with it, I feel sure that he would have been even more convinced that BOYLE,

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wont to breath here below. And that this Conjecture may not appear extravagant, I shall on this occasion subjoyn a memorable Relation that I have met with in the Learned *Josephus Acosta*, who tells us, That when he himself past the high Mountains of *Peru*, (which they call *Pariaecaca*) to which, he says, That the Alps themselves seem'd to them but as ordinary Houses, in regard of high Towers, he and his Companions were surprised with such extream Pangs of Straining and Vomiting, (not without casting up Blood too) and with so violent a Distemper, that he concludes he should undoubtedly have dyed, but that this lasted not above three or four hours, before they came into a more convenient and natural temperature of Air : To which our Learned Author addes an Inference, which being the principal thing I design'd in mentioning, the Narrative I shall set down in his own Words : *I therefore* (says he) *perswade myself, That the Element of the Air is there so subtle and delicate, as it is not proportionable with the breathing of Man, which requires a more gross and temperate Air; and I believe it is the cause that doth so much alter the Stomack, and trouble all the Disposition.* Thus far our Author, whose Words I mention, that we may ghess by what happens somewhat near the Confines of the Atmosphere (though probably far from the surface of it) what would happen beyond the Atmosphere. That which some of those that treat of the height of Mountains, relate out of *Aristotle*, namely, That those that ascend to the top of the Mountain *Olympus*, could not keep themselves alive, without carrying with them wet Spunges, by whose assistance they could respire in that Air, otherwise too thin for Respiration : (That Relation (I say) concerning this Mountain) would much confirm what has been newly recited out of *Acosta*, if we had sufficient reason to belive it : But, I confess, I am very diffident of the truth of it; partly because when I pass'd the *Alps*, I took notice of no notible change betwixt the consistence of the Air at the top and at the bottom of the Mountain." (pp. 355-58.)

(17) MAYOW, J. *Tractatus duo*, Oxford, 1668.

rather than MAYOW, deserves credit for the modern conception of respiration and combustion. The opening paragraph is typical of what follows : " Besides the four first Qualities of the Air, (Heat, Cold, Dryness and Moisture) that are known even to the Vulgar; and those more unobvious, that Philosophers and Chymists have discovered, such as Gravity, Springiness, the power of Refracting the beams of Light; &c. I have often suspected, that there may be in the Air some yet more latent Qualities or Powers differing enough from all these, and principally due to the Substantial Parts or Ingredients, whereof it consists. And to this conjecture I have been led, partly (though not only or perhaps chiefly) by considering the Constitution of that Air we live and breath in, which, to avoid ambiguities, I elsewhere call *Atmospherical* Air. For this is not, as many imagine, a Simple and Elementary Body, but a confus'd Aggregate of effluviums from such differing Bodies, that, though they all agree in constituting, by their minuteness and various motions, one great mass of Fluid matter, yet perhaps there is scarce a more heterogeneous Body in the world." (18)

After describing observations on the increase in weight of metals on heating in air, one finds the following suggestive passage : " The Difficulty we find of keeping Flame and Fire alive, though but for a little time, without Air, makes me sometimes prone to suspect, that there may be dispers'd through the rest of the Atmosphere some odd substance, either of a Solar, or Astral, or some other exotic, nature, on whose account the Air is so necessary to the subsistence of Flame; which Necessity I have found to be greater, and less dependent upon the *manifest* Attributes of the Air, than Naturalists seem to have observed. For I have found by tryals purposely made, that a small flame of a Lamp, though fed perhaps with a subtil thin Oyl, would in a large capacious glass-Receiver expire, for want of Air, in a far less time than one would believe." (19)

There are many other suggestive passages in this tract and another little-known work of BOYLE entitled *New Experiments touching the relation betwixt Flame and Air*, published in 1672,

(18) BOYLE, R. *Suspicions about Some Hidden Qualities of the Air*, London, 1674.
(19) BOYLE, R. *Ibid.*, p. 24, 25.

which indicate that BOYLE was clearly aware (1) of the heterogeneous character of the air, and (2) that respiration and combustion depended upon the presence in the air of some specific substance which was removed by either process. All of his statements, moreover, are characterized by the caution and reserve of a great scientist. From the facts already before you and from careful study of BOYLE's writings on combustion, it is clear that BOYLE approached the discovery of oxygen more closely than anyone before PRIESTLEY and LAVOISIER.

ATOMIC STRUCTURE AND THE KINETIC THEORY OF THE GASES

Mr. JOSHUA C. GREGORY of Leeds in his new and stimulating book on the history of atomism (20) has given an excellent discussion of the background of BOYLE's atomic theory. BOYLE was familiar with the ancient writers, LEUCIPPUS, DEMOCRITUS, LUCRETIUS and the Epicureans, but of his near contemporaries only GASSENDI and DESCARTES had revived the ancient theory. Since GASSENDI and DESCARTES were not experimentalists, BOYLE must be allowed the credit of having first examined the hypothesis experimentally and of elaborating it in truly scientific fashion—*pour préciser les idées.*

The transition from BOYLE's theories of combustion to his conception of the atom is not difficult to make since he was prone himself to mention them in the same breath. His work on the ' spring of the air ' which we have just discussed led him to consider the ultimate nature of gases and of matter in general, and he indicates clearly in this, his first scientific work, that he was already committed to a modified Cartesian system. His conception is set forth in preliminary form in *The Sceptical Chymist* (1661) and in *Certain Physiological Essays* (1661) but the theory is developed in much greater detail in *The Origine of Formes and Qualities* (1666). GREGORY (21) has remarked that the book is particularly significant in the history of Science because it repre-

(20) GREGORY, J. C. *A Short History of Atomism from Democritus to Bohr*, London, BLACK, 1931.

(21) *Ibid.*, p. 33.

sents, " the invasion of Science by corpuscular expositions through the dominating influence of DESCARTES. As BOYLE adopted his own private version of Cartesianism he expressed the scientific mind of his time in a welcome to the exiled atom that was returning as a corpuscle."

Nowhere in the history of Science can one find a more judicious and telling protest against the dominance of Greek learning than in BOYLE's Proemial Discourse to ' Formes and Qualities.' He inveighs against the schoolmen who slavishly follow ARISTOTLE (22) and then states in no uncertain terms his own *confessio fidei* concerning the work of the great Stagirite as follows : " And I here declare once for all, that where in the following Tract, or any other of my writings, I do *indefinitely* depretiate *Aristotle's* Doctrine, I would be understood to speak of *his Physicks*, or rather of the Speculative part of them, (for his Historical Writings concerning Animals I much esteem) nor do I say, that even these may not have their use among Scholars, and even in Universities, if they be retain'd and studied with due cautions and Limitations; (of which I have elsewhere spoken.)" (23)

His reservations concerning the Cartesians are similarly telling. " I have forborn to imploy Arguments," he says, " that are either grounded on, *or* suppose Indivisible Corpuscles call'd *Atoms*, or any *innate motion* belonging to them; *or* that the Essence of Bodies consists in Extension, *or* that a Vacuum is impossible; *or* that there are such *Globuli coelestes*, *or* such a *Materia subtilis*, as the Cartesians imploy to explicate most of the *Phaenomena* of Nature." (24) BOYLE's subsequent treatment of the " cor-

(22) BOYLE, R. *The Origine of Formes and Qualities*, Oxford, 1667, f. Ab5*b* : " I also forbear to answer Arguments, that however vehemently and subtly urg'd by many of the modern Schoolmen of the Roman Catholick Communion, are either confessedly, or at least really built upon some Theologicall Tenents of theirs, which being oppos'd by the Divines of other Churches, and not left unquestion'd by some Acute ones of their own, would not be proper to be solemnly taken notice of by Me, whose businesse in this Tract is to discourse of Natural things as a Naturalist, without invading the Province of Divines, by intermedling with Supernatural Mysteries, such as those, upon which divers of the Physico-Theologicall Tenents of the Schoolmen, especially about real Qualities, and the Separablenesse of Accidents from Subjects of Inhesion, are *manifestly*, if not also *avowedly* grounded. "

(23) *Ibid.*, f. Ab7*a*.

(24) *Ibid.*, f. Ab5*a*.

puscular " philosophy is conservative and at every point he is careful to distinguish between fact and theory. He considered the corpuscular theory of the world highly probable though unproved. We cannot here go into the full details of his argument and we must omit discussion of his doctrine of ' qualities,' the forerunner of the Newtonian conception of light, since this has been recently dealt with by IRVINE MASSON. (25)

In an oddly named tract, *An Essay of the Great Effect of Even Languid and Unheeded Motion* (1685), one finds BOYLE's theory of matter set forth in an even more complete form. His earlier works were richer in the record of experiment but his interpretations were then less mature. In his tract, " He first draws attention to the ' great effects ' which can be propagated by the air (*e.g.*, breaking of distant windows by cannon), and reiterates that any moving body whether liquid, gaseous or solid, evolves heat on encountering an impediment." Some passages suggest, " that he was thinking of a ' mechanical equivalent of heat ' and that he regarded heat itself as due to small particles of matter in ' local motion.' He also asks himself, parenthetically, whether lode-stones produce their influence through agitation of air particles, but he concluded in the negative on finding that iron filings are still affected when in a vacuum." (26) There are many passages in which he discusses the vibration of the ultimate particles of substances. On page 115, for example, he remarks, " That diamonds themselves will by rubbing upon woolen clothes be made electrical, seems to argue, that their Parts are set amoving."

BOYLE's virtual statement of the modern kinetic theory of gases occurs in a book published a few months after his death, entitled *The General History of the Air*. The book begins with a definition of the air which runs as follows : " By the *Air* I commonly understand that thin, fluid, diaphanous, compressible and dilatable Body in which we breath, and wherein we move, which envelops the Earth on all sides to a great height above the highest Mountains ; but yet is so different from the *Aether* [or *Vacuum*] in the intermundane or interplanetary Spaces, that it refracts the Rays of

(25) MASSON, IRVINE. *Three Centuries of Chemistry. Phases in the Growth of a Science*, London, 1925.

(26) FULTON, J. F. " A Bibliography of the Honourable Robert Boyle," Proc. Oxf. Bibliog. Soc., 1932, *iii*, 1-160. (p. 101.)

the Moon and other remoter Luminaries." In another place he remarks, " It seems then not improbable to me, that our *Atmospherical* Air may consist of *three* differing Kinds of Corpuscles." Then on pages 6 and 7 occurs the following remarkable passage : " Only I shall here intimate, that though the Elastical Air seem to continue such, rather upon the score of its Structure, than any external Agitation; yet Heat, that is a kind of Motion, may make the agitated Particles strive to recede further and further from the Centers of their Motions, and to beat off those, that would hinder the freedom of their Gyrations, and so very much add to the endeavour of such Air to expand it self. And I will allow you to suspect, that there may be sometimes mingled with the Particles that are springy, upon the newly mentioned Account, some others, that owe their Elasticity, not so much to their Structure, as their Motion, which, variously brandishing them and whirling them about, may make them beat off the neighbouring Particles, and thereby promote an expansive Endeavour in the Air, whereof they are Parts." Making allowances for 17th-century diction, really no more complete or adequate statement of the kinetic theory of gases could have been offered.

It would be of some interest to know whether BOYLE studied the effect of temperature on the volume of gases. He was of course familiar with the expansion effect of heat, but the only detailed discussion which I have been able to find occurs in a brief and little-known tract called *A Discovery of the Admirable Rarefaction of the Air* published in 1671, and recording experiments carried out in 1662. Though he made no attempt to determine the coefficient of expansion of a gas for a degree of temperature, he remarks : " Furthermore, It may seem worth while, to observe, how much the utmost degree of Rarefaction by Heat, that Experiment has shewed us of the Air, falls short of the Degree of Expansion, to which it has been advanced in our Pneumatical Engine, the proportion betwixt these two Expansions being that of 1 to 70, or therabout." (27)

He also considers the volume of a bubble when the pressure is reduced : " To some perhaps it will seem more fit to consider,

(27) BOYLE, R. *Tracts. Of a Discovery of the Admirable Rarefaction of the Air*, etc., London, 1671, p. 25.

than easie to resolve, how, since the Corpuscles of the Air are acknowledg'd to be heavy, and those that remain, must be so wonderful thinly disperst, in the Cavity of the Receiver they come to be supported, and kept as it were swimming therein, and do not appear to subside by their own weight, the *Materia subtilis* (though the presence of that should be admitted) not appearing to have gravity, wherewith to sustain them; and the *Vacuum* (if that be suppos'd wherever the Aerial Particles are not) being too near a-kinne to nothing, to be able to oppose their descent: but though something may be suggested about the solution of this doubt, my haste obliges me to leave it such." (28)

VI

It now remains to give the evidence for the assertion that BOYLE influenced men of all walks of life in the 17th century and that his works were widely read. One cannot urge that the number of books published by a writer bears evidence of his popularity. However, in the case of BOYLE it is clear that his works were much sought after by printers for they often brought them out almost simultaneously in English and in Latin, and the frequent reprintings (29) would not have been undertaken had the books not sold widely. The large number of Continental reprints also speaks for their wide distribution. (30) The *Seraphick Love*, for example, had ten editions in English, two in Latin, one in French, and one in German. There are more than 200 entries in the bibliography of his separately published books, which would mean an average of nearly five editions of each separate publication. In addition to this his complete works in English were twice reprinted during the 18th century.

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(28) *Ibid.*, p. 26.

(29) In his prefaces BOYLE often mentions that his books had sold well. Thus in the 'Proemial Discourse' to *Formes and Qualities* he says: "Having four or five years ago publish'd a little Physico-Chymical Tract about the differing parts and redintegration of Nitre, I found as well by other signs as by the early sollicitations of the Stationer for a new Edition, that I had no cause to complain of the reception that had been given it." (f. Ab1*a*.)

(30) With one or two exceptions all BOYLE's writings appeared in Latin on the Continent within a few years, and sometimes within a few months, of their publication in England.

Evidence of another sort is to be derived from the great number of books dedicated to BOYLE in the course of his life. I was able to list ten in my bibliography and two others have recently come to light : one a book by DANIEL GOOKIN, (31) an American

(31) GOOKIN, DANIEL. " Historical Collections of the Indians in New England," first printed from the original manuscript dated December 7, 1674, in *Collections Mass. Histor. Soc.*, 1792, i, 141-227 (Vol. I reprinted in Boston, 1806). The work is prefaced by " The Epistle Dedicatory " to Prince CHARLES followed by,

"An EPISTLE Gratulatory and Supplicatory

"*To the Right Honourable the Corporation for propagating the gospel in America, residing in London; and particularly for the Hon. Robert Boyle, Esquire, Governour thereof.*

"Right Honourable,

"These Collections do, in a special manner, implore your favourable aspect and protection; for God hath been pleased to honour and employ you, as eminent instruments to encourage and promote this great affair of his kingdom in this western world, for propagating the gospel of Christ among the poor and desolate Indians.

"The unworthy penman hereof desireth in all humility, to offer three words to your Honours.

"First, with all cordial acknowledgment, I thank your Honours for all that great condescension and labour of love, that from time to time you have shewed in your zealous and faithful promoting of this work, committed unto your care and trust by his Majesty.

"Secondly, to supplicate your unwearied countenance therin, and putting forth, not only your prayers, but, vigorous endeavours to further it; for truly the work is great, and that in special as it relates to the glory and honour of the great God, and his only Son, our Saviour Jesus Christ, in the salvation of these poor gentiles.

"Thirdly, that you will please to peruse, and seriously to consider, and, if it may suit with your wisdoms, put in practice, these proposals, that I have presumed to make in the 12th Chap. of this tractate, as a means, under God, to civilize the barbarous Indians, and propagate religion among them; especially in setting up some free schools to teach them to speak, read, write, and understand, the English tongue.

"So praying unto the God of all grace, to multiply upon every one of you, his richest and best blessings, I take leave, and remain,

"Right Honourable,
"your humble servant,
"DANIEL GOOKIN, Sen.

"Cambridge, in N.E. Dec. 7th, 1674."

GOOKIN also dedicated another work to BOYLE entitled " An Historical Account of the doings and sufferings of the Christians Indians in New England, in the year 1675, 1676, 1677," which was first printed in *Trans. and Collect. Amer. Antiq. Soc.*, 1836, ii, 423-534. " The Epistle Dedicatory " is dated Cambridge in N.E., December 18th, 1677. As far as I am aware these are the only contemporary dedications to BOYLE from the American colonies. I am greatly indebted to Dr. HERBERT THOMS, of the Yale School of Medicine, for directing my attention to them.

writer on Indian customs, and the other by JOHN EVELYN. (32) The esteem in which he was held is perhaps to some extent indicated too by the fact that his funeral sermon was reprinted four times and that at the time of his death five different necrological sheets and elegies appeared from the London presses within a period of a few weeks. (33)

Much more eloquent, however, is the evidence to be derived from the works of his contemporaries. The diaries of EVELYN and PEPYS abound in references to BOYLE, several of which may be quoted. EVELYN was evidently one of BOYLE's closest friends and certainly one of his warmest admirers. A considerable part of their correspondence has been preserved. On September 29, 1659, EVELYN wrote, after reading the manuscript of *Seraphick Love*, " I extremely loved you before; but my heart is infinitely knit to you now." (34) On September 13, 1661, he wrote him again : " I have not bought two of your last books, & yet possibly I could render you some account of them. My thirst and impatience is too great to shew the least indifferency, when any thing of your's is to be had; this does not absolve you from making him a present who, it may be, takes no greater felicity in the world than to see his small library enriched with your illustrious works, & they to come to me *ex dono authoris*." (35) Under November 30, 1680 (St. Andrew's Day) is a more significant passage written in Evelyn's maturer years : " The anniversary election at the Royall Society, brought me to London, where was chosen President that excellent person and greate philosopher Mr. Robert Boyle, who indeede ought to have ben the very first; but neither his infirmitie nor his modestie could now any longer excuse him." (36)

In EVELYN's diary there are also many references to BOYLE's individual experiments, the following of which may be cited : " May 7th. [1662] I waited on Prince Rupert to our Assembly,

(32) *Diary of John Evelyn*, edited by H. B. WHEATLEY, 4 vols., London, 1906, *ii*, 147 : " 10th. [June, 1662] I returned to London, and presented my ' History of Chalcographie ' (dedicated to Mr. BOYLE) to our Society."

(33) Full details concerning these sheets are to be obtained in the Bibliography of BOYLE, see 12.

(34) EVELYN, *op. cit.*, *iii*, 273.

(35) *Ibid.*, *iii*, 281.

(36) *Ibid.*, *ii*, 374. BOYLE, however, declined the chair.

where were tried severall experiments in Mr. Boyle's *vacuum*. A man thrusting in his arme upon exhaustion of y^e^ aire had his flesh immediately swelled so as the bloud was neere bursting the veines : he drawing it oute we found it all speckled." (37) " 24th. [October, 1664]... I went to visit Mr. Boyle (now here), whom I found with Dr. Wallis and Dr. Ch^r^ Wren in the tower of the scholes, with an inverted tube or telescope, observing the discus of y^e^ sunn for y^e^ passing of Mercury that day before it." (38)

The references to BOYLE in PEPYS' Diary (39) are amusing and reflect the attitude of a layman confronted for the first time by a scientific treatise. Thus on April 28, 1667 PEPYS noted : " and so to supper and to read, and so to bed, mightily pleased with my reading of Boyle's book of colours to-day, only troubled that some part of it, indeed the greatest part, I am not able to understand for want of study." (40) A little later (May 26), referring to the same work, " I took another book, Mr. Boyle's of Colours, and there read, where I laughed, finding many fine things worthy observation." (41) A third reference to the book occurs on June 2 : " Being weary and almost blind with writing and reading so much to-day, I took boat at the Old Swan, and there up the river all alone as high as Putney almost, and then back again, all the way reading, and finishing Mr. Boyle's book of Colours, which is so chymical, that I can understand but little of it, but understand enough to see that he is a most excellent man." (42) On June 10 he had started another of Boyle's works : " So I homeward, as long as it was light reading Mr. Boyle's book of Hydrostatics, which is a most excellent book as ever I read, and I will take much pains to understand him through if I can, the doctrine being very useful." (43) Similarly, on July 24 : " all the way with extraordinary content reading of Boyle's Hydrostatickes, which the more I read and understand,

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(37) *Ibid.*, *ii*, 144.
(38) *Ibid.*, *ii*, 170.
(39) PEPYS, S. *The Diary*, edited by H. B. WHEATLEY, London, 1920, 9 vols.
(40) *Ibid.*, *vi*, 292,
(41) *Ibid.*, *vi*, 338.
(42) *Ibid.*, *vi*, 347.
(43) *Ibid.*, *vi*, 358.

the more I admire, as a most excellent piece of philosophy." (44) A further amusing reference to ' Formes and Qualities ' appears on April 1, 1668 : " Thence called at my bookseller's, and took Mr Boyle's Book of Formes, newly reprinted, and sent my brother my old one." (45)

There are many other references to BOYLE in the writings of his literary contemporaries, particularly among theologians and those theologically inclined. A large part of his extensive correspondence with scientists at home and abroad has also survived, but this has already been described in the excellent biographies of BIRCH (46) and FLORA MASSON. (47)

The recently published *Conway Letters*, (48) which consists largely of the correspondence between ANNE CONWAY and HENRY MORE, contain many allusions to BOYLE deserving of special mention. It should be recalled that BOYLE and MORE came into conflict over BOYLE's hydrostatical experiments. (49) MORE's initial scepticism, which incidentally was quite unfounded, is seen in the following passages : " I will bring Mr Boiles Hydrostaticks with me, which I made bold to carry away upon a presumption I should sooner have returned. It is a very pleasant discourse, though I be not altogether satisfyde that his paradoxicall Inferences from the experiments are true. There will be a Spiritt of Nature for all this, and I think for anything that ever will be alledg'd to the contrary, or excogitated to evade the unrelish of that principle." (50) And again on April 28, 1666 : " Dr. Cudworths little son has received reall good from Mr Greatrakes, and Mr Boyle told me that he had been a spectatour of at least 60 performances of his. I believe that gentleman is likely to doe him more creditt then any body. Mr Boyle resented Dr Stubs his letter very ill, I perceiv'd by what he sayd to me.

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(44) *Ibid.*, *vii*, 35.

(45) *Ibid.*, *vii*, 386.

(46) BIRCH, T. *The Works of the Honourable Robert Boyle in Five Volumes : To which is prefixed The Life of the Author*, 1st ed., London, 1744.

(47) MASSON, FLORA. *Robert Boyle : A biography*, London, 1914.

(48) *Conway Letters*, edited by MARJORIE HOPE NICOLSON, New Haven, Yale University Press, 1930.

(49) BOYLE, R. *Hydrostatical Paradoxes*, Oxford, 1666.

(50) *Conway Letters*, p. 269. HENRY MORE to LADY CONWAY, March 17, 1666.

I know not how the Doctor will come off." (51) After BOYLE had replied, (52) MORE assumes a rather disturbed tone in reference to the controversy : " Mr Boyle does not take my dissenting so from him in publick so candidly as I hoped, which I am very sorry for. For he is a person that I have a singular honour and esteeme for as I do cordially and simply declare in the book in which I meddle with his notions, and thought Philosophy had been free. If any body had confuted any thing of mine with such circumstances as I have done, I cannot perceive that that would have given me the least disgust in the world. If he were mistaken I would with the same kindnesse demonstrate his errour to the world, and lett them judge." (53)

There are also a series of amusing passages concerning *Ens veneris*, (54) one of BOYLE's medicines which had been recommended to LADY CONWAY by HENSHAW : " Dr Hernshaw perswades me to make tryall of a medison of Mr Boyles called, Ens Veneris. I hade some of the powder from him, but because he bought it, I am fearfull it may not be so well prepared as what you may be able to procure from his owne hand, which I suppose you may easily doe by my Lord of Orrerys meanes, and mineralls are not safely made use of if any error be committed in the making of them. Dr Hearnshaw thinks it good for the scurvy and for a weak stomach, and says Mr Boyle commends it for an invetterate headache, but if you have an oppertunity of discoursing with himself he is best able to give an account of the effects of his owne medison, and it being easie to take I am willing to make tryall of it. I believe I am hugely afflicted with the scurvy, and am so very much indisposed all over, that I should be very glad to have some discourse with the physitians, if I were at London." (55)

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(51) *Ibid.*, p. 273. HENRY MORE to LADY CONWAY, April 28, 1666.

(52) BOYLE, R. *New Experiments, touching the Relation betwixt Flame and Air. And about Explosions. An Hydrostatical Discourse oc-casion'd by some Objections of Dr. Henry More against some Explications of New Experiments made by the Author of these Tracts*, Oxford, 1672.

(53) *Conway Letters*, p. 358. HENRY MORE to LADY CONWAY, May 11, 1672.

(54) BOYLE, R. *Of the Reconcileableness of Specifick Medicines to the Corpuscular Philosophy*, London, 1685. (P. 201.)

(55) *Conway Letters*, p. 225. LADY CONWAY to her husband, September 4, 1664. Also pp. 226, 228, 229, 230.

VII

SUMMARY AND CONCLUSION

Toward the end of the 19th century, Science had been accepted by the chief universities of the world and it had begun to shape the lives and thought of all civilized races of the Occident. Its recognition, however, had been slow, and its influence upon the course of human history has never been adequately traced. ROBERT BOYLE (1627-1692) was one of the first in Science whose work was widely read by the lay public, and through this circumstance he exerted a far more important influence than is commonly recognized. He wrote in a language that his contemporaries could understand, and he undoubtedly did more than anyone of his time to make Science a part of the intellectual equipment of educated men. BOYLE had never been a student at a university and throughout his active life he declined to occupy a chair. He touched nearly all branches of knowledge, however, and there is no division of modern Science, except possibly astronomy, which cannot trace phases of its origin in his writings. In addition to his well known contribution to the gas laws he was the first modern protagonist of the atomic structure of matter and he gave a clear statement of the kinetic theory of gases. He studied respiration, the chemical nature of blood and urine, magnets and electricity; but of even greater importance was the enunciation of a theory of combustion and respiration which recognized the dependence of the process on a substance extracted from the air. As Professor T. S. PATTERSON has recently shown, MAYOW's theory of combustion was drawn largely from BOYLE without acknowledgment. BOYLE's contribution to Science was thus great, but it is urged that his success in placing Science on an equal footing with the other intellectual disciplines represents an even more far-reaching achievement.

New Haven, Connecticut. J. F. FULTON.

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